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Direct Effect of Silicon and Sulphur on Nutrient Content and Uptake of Rice Crop under Rice-Wheat Cropping Sequence

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A B S T R A C T

The field experiment was conducted on "Effect of silicon and sulphur on yield and chemical composition on rice and its residual effect on wheat in loamy sand soil" during the *kharif* and *rabi* seasons for two years 2016-17 and 2017-18 at Regional Research Station farm, Anand Agricultural University, Anand (Gujarat). The experiment was laid out in Randomized Block Design with factorial concept, comprising twelve treatment combinations of four levels of silicon (0, 150, 300 and 450 kg Si ha^{-1}) and three levels of sulphur (0, 20 and 40 kg S ha^{-1}) with three replications. The maximum Si and S content in grain and straw was noticed due to combined application of 450 kg Si ha^{-1} and 40 kg S ha^{-1}. Significantly higher phosphorus content in grain and straw was found under application of 450 kg Si ha^{-1}.No significant change in P content in grain and straw were observed with varying levels of S application. Significantly highest Si and S uptake by rice grain and straw was observed under highest Si application (450 kg Si ha^{-1}) with highest S level at 40 kg ha^{-1} over rest of the combinations. The maximum P uptake by rice grain and in rice straw was recorded due to application of 450 kg Si ha^{-1} during both the years as well as on pooled basis respectively. Addition of sulphur increased P uptake by grain and the maximum uptake was recorded at 40 kg S ha^{-1} during second year and pooled basis.

Introduction

Silicon content in different parts of a rice plant generally ranged from high to low, in descending rank in the hull, leaf, leaf sheath, culm, and root (Zhu, 1985). Silicon helps plants to overcome multiple stresses including biotic and abiotic stresses (Ma, 2004). For example, Si plays an important role in increasing the resistance of plants to pathogens such as blast on rice (Datnoff *et al.*, 1997) and also alleviates the effects of other abiotic stresses including salt stress, metal toxicity, drought stress, radiation damage, nutrient imbalance, high temperature, and freezing (Ma and Takahashi, 2002). In crop production the benefits from Si fertilization may include increased yield, disease and insect resistance and tolerance to stresses such as cold, drought, and toxic metals. Rice, wheat, cucurbits, corn and sugarcane are crops that have been shown to benefit from Si fertilization. In addition to crops, the value of silicon is gaining attention in animal nutrition where Si may play a role in the health of bone, joints, skin, hair and connective tissues. Si exists in all plants grown in soil and its content in plant tissue ranges from 0.1 to 10%.

Sulphur (S) is one of the sixteen essential plant nutrients and ranks fourth major nutrient next to N, P and K. Crop requires sulphur generally as much phosphorus and one tenth of nitrogen. Among the essential elements, sulphur is very much beneficial for increasing the production of rice and is one of the major essential nutrient elements involved in the synthesis of chlorophyll, certain amino acids like methionine, cystine, cysteine and some plant hormones such as thiamine and biotin (Rahman *et al.,* 2007). Accumulation of inorganic nitrogen or organic non-protein nitrogen in the tissue, leaf area, seed number plant^{-1}, floral initiation and anthesis in plants are affected by the presence or absence of sulphur (Tiwari, 1994). Growing of sulphur responsive crops, high intensive cropping and use of sulphur free fertilizers caused S deficiency in soils of India (Tandon and Tiwari, 2007).

Paddy is considered as silicon accumulator. An adequate supply of silicon to paddy from tillering to elongation stage increases the number of grains per panicle and enhances ripening (Korndorfer *et al.*, 2001). It is also suggested that the silicon plays a crucial role in preventing or minimizing the lodging incidence in the cereal crops, a matter of great importance in terms of crop productivity. Rice is the staple food of about half of the world's population. The benefits from Si fertilization may include increased yield, enhanced disease and insect resistance and tolerance to stresses such as cold, drought and toxic metals. Various crops like wheat, cucurbits, corn and sugarcane have been shown to be benefited from Si fertilization.

Materials and Methods

The field experiment was conducted during the *kharif* season for two years 2016-17 and 2017-18 at the Regional Research Station, Anand Agricultural University, Anand, Gujarat. The soil of the experimental field was loamy sand in texture with the pH of 7.8 and organic carbon 0.30 %. The soluble salts (EC) content was medium and an overall mean value of 0.23 dS m^{-1}.The status of available nutrients like Si (68.73 mg kg^{-1}), P_2O_5 (32.58 kg ha^{-1}), S (9.81 mg kg^{-1}), Fe (7.31 mg kg^{-1}) and Zn (1.23 mg kg^{-1}). The treatment comprised of four levels of silicon (Si) (0, 150, 300 and 450 kg ha^{-1} through calcium silicate) and three levels of sulphur (S) (0, 20 and 40 kg ha^{-1} through bentonite sulphur) were applied as basal along with recommended NPK dose of fertilizers (120: 40: 00 kg ha^{-1}). The experiment was laid out in factorial randomized block design with three replications. Available silicon in the soils was extracted by using NaOAc (14.8 g NaOAc+49.2 mL acetic acid L^{-1}, adjusted to pH 4, Sample: solution=10 g: 100 ml, 1 hr. shaking) and silicon in the extracting solution was determined by taking 1 ml of aliquot from filtrate into plastic centrifuge tube, 30 mL of acetic acid and 10 mL of ammonium molybdate solution (54 g L^{-1} pH 7) and then after 5 minutes, 5 mL of 20% tartaric acid solution and after two minutes, 1 mL reducing agent ANSA (1-amino-2- naphthol-4-sulphonic acid) were added and final volume was made upto 50 mL with 20% acetic acid. Within thirty minutes, concentration of silicon was measured as absorbance at 650 nm on UV, Visible Spectrophotometer (Korndorfer *et al.,* 1999).

For the plant samples the powered sample (0.1g) was digested in a mixture of 2 mL of 50% H_2O_2 and then 4.5 mL of 50% NaOH was added at ambient temperature in each polypropylene 100 mL tube. The tubes were individually covered with loose fitting plastic cups. The rack of tubes was placed in an autoclave (15 psi & 138 Kpa) for one hour. The volume of digested contents in the tubes was made up to 50 mL with double distilled water and after filtration; 1 mL aliquot was taken for Si estimation (Dai *et al.,* 2005). The Si concentration in the digested solution was determined by 1 mL of digested aliquot. It was transferred to a plastic centrifuge tube and 30 mL of 20% acetic acid, 10 mL of ammonium molybdate (54 g L^1 pH 7), 5 mL of 20 % tartaric acid and 1 mL of reducing *ANSA* solution (1-amino-2- naphthol-4-sulphonic acid*)* were added and the volume was made up to 50 mL with 20% acetic acid. After 30 minutes, the absorbance was measured at 650 nm on UV, Visible Spectrophotometer (Dai *et al.,* 2005). Similarly, 100 ppm SiO_2 strength and a stock solution of Si standards (0, 0.2, 0.4, 0.8 and 1.2 ppm) were prepared by following the same procedure and silicon concentration was measured on spectrophotometer to find out the graph factor from a standard curve by plotting Si concentration on X axis and optical density on the Y axis. Nutrient uptake by both grain and straw of rice and wheat was calculated using the values of nutrient content and yield of grain and straw (kg ha^{-1}). The experimental data were analyzed as per the procedure outlined by Steel and Torrie (1982).

Results and Discussion

The application of Si significantly affected Si content in grain of rice. Significantly highest average silicon content in grain (2.22 %) was found under application of 450 kg Si ha^{-1} over rest of the treatments. Application of 40 kg S ha^{-1} significantly increased the average Si content in grain (1.79 %). The maximum Si content in grain was noticed due to combined application of 450 kg Si ha^{-1} and 40 kg S ha^{-1} (Table 1). Significantly highest average silicon content in straw (6.78 %) was found under application of 450 kg Si ha^{-1} over rest of the treatments. Application of 40 kg S ha^{-1} significantly increased the average Si content in straw (5.67 %). The maximum Si content in straw was noticed due to combined application of 450 kg Si ha^{-1} and 40 kg S ha^{-1} (Table 2). The nutrients content in rice significantly affected by silicon and sulphur application and similar results also obtained by Deren *et al.,* (1994) and marked that increase in Si concentration in plant tissue with increasing rate of Si fertilization and cultivars differed for Si concentration and its uptake, thus, stressed the necessity for identifying or developing rice genotypes which are more efficient in accumulating available Si which may be of particular benefit on Si deficient soils. Hayasaka *et al.,* (2005) reported that the response of rice plants to Si fertilization depends on soil factors such as Si availability to the plant and on plant factors such as the Si content of plant tissues. The amount of available Si in soils varies with soil composition. Thus, the Si content depends on the kind of soil used. In their study, application of silica gel effectively increased the Si content of nursery seedlings regardless of soil type. The results are in agreement with the findings of Islam and Saha (1969); Inanaga *et al.,* (2002); Shivay and Dinesh Kumar (2009) and Idris *et al.,* (1975).

The maximum average S content in grain (0.172 %) was noticed at maximum level of Si application. The maximum increment over control was to the tune of 39.83 per cent higher on a pooled basis. Among the various S levels, application of 40 kg S ha^{-1} produced significantly higher average S content in grain (0.164 %). The maximum increment over control was to the tune of 33.35 per cent higher on pooled basis. The highest S content in grain was noticed due to combined effect of 450 kg Si ha^{-1} and 40 kg S ha^{-1} application

(Table 1). The maximum average S content in straw (0.123 %) was noticed at maximum level of Si application. The maximum increment over control was to the tune of 38.20 per cent higher on a pooled basis. Among the various S levels, application of 40 kg S ha^{-1} produced significantly higher average S content in straw (0.129 %). The maximum increment over control was to the tune of 67.46 per cent higher on pooled basis. The highest S content in straw was noticed due to combined effect of 450 kg Si ha^{-1} and 40 kg S ha^{-1} application (Table 2). Increase in Si levels ultimately increased the absorption of sulphur and CO_2 thus it blocks the hatches and improve the photosynthesis (Gerami *et al.,* 2012). Tiwari *et al.,* (1983) and Hoque and Eaqub (1984) reported that sulphur application increased its content in grain and straw. The findings of the present study are in conformity with the results reported by Mandata *et al.,* (1994) who noted that concentration of Si in rice plant increased with increasing rates of S application. Islam *et al.,* (1987) reported that the highest S content in plant was noted when 30 to 40 kg S ha^{-1} were added to the soil. The increased in sulphur content of straw by Si application might be due to greater availability of this nutrient. Malidareh *et al.,* (2009) reported that sulphur content in rice straw increased with increasing Si application

Significantly higher phosphorus content in grain was found under application of 450 kg Si ha^{-1}.The P content in grain was increased from 0.194 to 0.249 %, 0.198 to 0.253 % and 0.196 to 0.251 % during both the years as well as on pooled basis, respectively (Table 1). Significantly higher phosphorus content in straw was found under application of 450 kg Si ha^{-1}. The P content in straw was increased from 0.076 to 0.106 %, 0.071 to 0.115 % and 0.073 to 0.112 % during both the years as well as on pooled basis, respectively. No significant change in P content in grain and straw were observed with varying levels of S application (Table 2). Owino and Gascho (2004) indicated that the P content increased when Si was applied, which could be attributed to the increase in the soil pH from the accompanying Ca and Si concentration in the soil solution, which improved the conditions for uptake of P by maize. Similar results were also recorded by Ma and Takahashi (2002) and Hellal *et al.,* (2012). Increased P in grain and straw could be attributed to enhanced translocation of P from roots to shoots due to Si application (Wang *et al.,* 2001). Sauer and Burghardt (2000) also opined that when P is not applied, Si fertilization increased the P content of rice straw and grain which could be attributed to better availability of native soil P and enhanced mobility of P from the roots to the stem. The beneficial effect of Si when available P is low can be explained as a partial substitution of Si for P (Ma and Takahashi 1990). In the absence of Si, a considerable decrease in the incorporation of inorganic phosphates into ATP and ADP and sugar phosphate has been observed in sugar cane (Wong You Cheong *et al.,* 1973).

The application of Si (450 kg ha^{-1}) resulted in maximum Si uptake by rice grain (139.58 kg ha^{-1}). The Si uptake by rice grain was observed significantly highest at S_{40} level as compared to S_{20} and S_0 levels. The values were ranged from 88.71 to 112.47 kg ha^{-1}. Significantly highest Si uptake in rice grain was observed under highest Si application (450 kg Si ha^{-1}) with highest S level at 40 kg ha^{-1} (174.32 kg ha^{-1}) over rest of the combinations (Table 3).

Significantly highest Si uptake by straw was noticed due to application of 450 kg Si ha^{-1}. The value was in range of 292.08 to 536.12, 324.26 to 564.49 and 308.17 to 550.39 kg ha^{-1} during both the years as well as on pooled basis respectively, over control.

Table.1 Effect of silicon and sulphur on silicon, sulphur and phosphorus content of rice grain under rice – wheat cropping sequence

	Silicon content (%) in grain			Sulphur content (%) in grain			Phosphorus content (%) in grain		
Treatment	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Silicon levels (kg ha^{-1})									
Si_0	1.12	1.23	1.18	0.120	0.127	0.123	0.194	0.198	0.196
Si_{150}	1.35	1.46	1.41	0.137	0.143	0.140	0.215	0.215	0.215
Si_{300}	1.87	1.99	1.93	0.153	0.162	0.157	0.232	0.237	0.134
Si_{450}	2.16	2.27	2.22	0.169	0.175	0.172	0.249	0.253	0.251
S.Em. ±	0.05	0.06	0.04	0.004	0.003	0.003	0.007	0.005	0.004
CD (P=0.05)	0.14	0.18	0.11	0.011	0.009	0.008	0.020	0.016	0.011
Sulphur levels (kg ha^{-1})									
S_0	1.54	1.59	1.56	0.120	0.125	0.123	0.217	0.219	0.218
S_{20}	1.64	1.73	1.69	0.154	0.161	0.158	0.223	0.226	0.225
S_{40}	1.71	1.88	1.79	0.161	0.168	0.164	0.227	0.231	0.229
S.Em. ±	0.04	0.05	0.03	0.003	0.003	0.002	0.006	0.005	0.003
CD (P=0.05)	0.12	0.16	0.10	0.009	0.008	0.007	NS	NS	NS
Significant interactions	Si × S	Si × S	Si × S	Si × S	Si × S	Si × S	-	-	-
CV %	8.59	10.80	8.51	7.75	6.04	5.51	9.25	7.24	9.55

Table.2 Effect of silicon and sulphur on silicon, sulphur and phosphorus content of rice straw under rice – wheat cropping sequence

	Silicon content (%) in straw			Sulphur content (%) in straw			Phosphorus content (%) in straw		
Treatment	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Silicon levels (kg ha^{-1})									
Si_0	4.08	4.41	4.24	0.081	0.098	0.089	0.076	0.071	0.073
Si_{150}	5.21	5.54	5.38	0.093	0.108	0.101	0.088	0.091	0.089
Si_{300}	5.80	6.14	5.97	0.105	0.121	0.113	0.097	0.102	0.098
Si_{450}	6.65	6.91	6.78	0.116	0.131	0.123	0.106	0.115	0.112
S.Em. ±	0.16	0.21	0.17	0.002	0.003	0.002	0.002	0.003	0.002
CD (P=0.05)	0.48	0.62	0.49	0.007	0.008	0.005	0.006	0.008	0.005
Sulphur levels (kg ha^{-1})									
S_0	5.40	5.63	5.52	0.080	0.085	0.083	0.089	0.093	0.091
S_{20}	5.43	5.76	5.59	0.098	0.104	0.101	0.091	0.095	0.093
S_{40}	5.47	5.87	5.67	0.120	0.138	0.129	0.094	0.097	0.096
S.Em. ±	0.14	0.18	0.14	0.002	0.002	0.002	0.002	0.002	0.001
CD (P=0.05)	NS	NS	NS	0.006	0.008	0.004	NS	NS	NS
Significant interactions	-	-	-	Si × S	Si × S	Si × S	-	-	-
CV %	9.06	11.06	6.60	7.28	6.99	7.81	6.58	8.52	9.60

Table.3 Effect of silicon and sulphur on silicon, sulphur and phosphorus uptake by rice grain under rice – wheat cropping sequence

	Silicon uptake (kg ha^{-1}) by grain			Sulphur uptake (kg ha^{-1}) by grain			Phosphorus uptake (kg ha^{-1}) by grain		
Treatment	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Silicon levels (kg ha^{-1})									
Si_0	63.80	70.45	67.12	6.79	7.28	7.03	11.03	11.34	12.18
Si_{150}	78.43	84.89	81.66	7.96	8.25	8.12	12.43	12.49	12.46
Si_{300}	110.46	118.37	114.41	9.05	9.67	9.36	13.74	14.10	13.92
Si_{450}	135.28	143.86	139.58	10.62	11.15	10.88	15.52	15.93	15.72
S.Em. ±	3.04	4.18	2.62	0.28	0.24	0.24	0.56	0.42	0.39
CD (P=0.05)	8.93	12.28	7.74	0.83	0.72	0.70	1.66	1.25	1.15
Sulphur levels (kg ha^{-1})									
S_0	86.83	90.60	88.71	6.80	7.12	6.96	12.30	12.52	12.41
S_{20}	97.98	103.82	100.89	9.16	9.63	9.39	13.32	13.50	13.44
S_{40}	106.18	118.77	112.47	9.86	10.52	10.19	13.91	14.38	14.14
S.Em. ±	2.63	3.62	2.28	0.24	0.21	0.20	0.49	0.37	0.34
CD (P=0.05)	7.74	10.64	6.71	0.72	0.62	0.61	NS	1.09	1.00
Significant interactions	Si × S	Si × S	Si × S	Si × S	Si × S	Si × S	-	-	-
CV %	9.43	12.04	10.35	9.97	8.13	5.37	12.91	9.56	9.98

Table.4 Effect of silicon and sulphur on silicon, sulphur and phosphorus uptake by rice straw under rice – wheat cropping sequence

	Silicon uptake(kg ha^{-1}) by straw			Sulphur uptake (kg ha^{-1}) by straw			Phosphorus uptake(kg ha^{-1}) by straw		
Treatment	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Silicon levels (kg ha^{-1})									
Si_0	292.08	324.26	308.17	5.78	7.17	6.48	5.42	5.58	5.50
Si_{150}	383.36	418.92	401.14	6.83	8.19	7.51	6.49	6.73	6.61
Si_{300}	441.08	472.63	456.86	8.06	9.38	8.72	7.38	7.39	7.38
Si_{450}	536.12	564.49	550.39	9.43	10.93	10.18	8.51	9.45	8.94
S.Em. ±	12.48	18.42	16.48	0.28	0.30	0.25	0.25	0.20	0.18
CD (P=0.05)	54.21	54.20	48.34	1.12	0.90	0.75	0.75	0.58	0.53
Sulphur levels (kg ha^{-1})									
S_0	389.79	413.42	401.60	5.80	6.26	6.03	6.44	6.74	6.59
S_{20}	414.25	447.40	430.82	7.25	7.75	7.50	6.94	7.30	7.12
S_{40}	435.44	474.41	454.92	9.52	12.37	11.13	7.46	7.82	7.64
S.Em. ±	16.00	15.84	14.27	0.24	0.26	0.22	0.22	0.17	0.15
CD (P=0.05)	NS	46.94	41.87	0.71	0.78	0.65	0.65	0.50	0.46
Significant interactions	-	-	-	Si × S	Si × S	Si × S	-	-	-
CV %	13.42	12.46	7.99	11.25	10.34	7.65	11.14	8.23	9.47

The Si uptake by rice straw was higher with 40 kg S ha^{-1} compared to 20 kg S ha^{-1}and 0 kg S ha^{-1} levels (Table 4). The silicon uptake is mainly dependent on Si supplying ability of the soil and with increased application of Si, there was increase in solubilisation of Si and thus Si uptake. These results are in agreement with the findings of Sumida (1992); Singh *et al.,* (2006); Osuna *et al.,* (1991) and Korndorfer *et al.,* (2001). This could be also due to increased root activity and enhanced soil nutrient availability. This is in accordance with the reports of Wani *et al.,* (2000). Further, the increased uptake with crop growth might be attributed to the increased DMP produced with growth of crop due to the enhanced release and consequent availability of nutrients to the crops.The silicon uptake was higher in straw compared to the uptake by grain at harvest. Ma and Takahashi (2002) reported that beneficial effects of Si exposed through silicon deposition in the leaves, stems and hulls. Therefore silicon is characterized by wide effects associated with greater Si accumulation in the shoots. Ma and Yamaji (2006) explained that the variation in the uptake values by the two verities could be due to differential expression of gene, which belongs to the Aquaporin family and is constitutively expressed in the roots. It is localized on the plasma membrane of the distal side of both exodermis and endodermis cells, where casparin strips are located.

Significantly higher S uptake by grain (10.88 kg ha^{-1}) was observed under Si application @ 450 kg Si ha^{-1}. Maximum S uptake by grain (10.19 kg ha^{-1}) was recorded at maximum level of S application. Significantly highest S uptake by rice grain was observed under highest Si application (450 kg Si ha^{-1}) with highest S level at 40 kg ha^{-1} (13.43 kg ha^{-1}) over rest of the combinations (Table 3). Significantly higher S uptake straw (10.18 kg ha^{-1}) was observed under Si application @ 450 kg Si ha^{-1}. Maximum S uptake by straw (11.13 kg ha^{-1}) was recorded at maximum level of S application. Significantly highest S uptake by rice straw was observed under highest Si application (450 kg Si ha^{-1}) with highest S level at 40 kg ha^{-1} (14.39 kg ha^{-1}) over rest of the combinations (Table 4). Silicon also favorably influenced the sulphur uptake showing its synergistic effect with silicon application as reported by Jawahar and Vaiyapuri (2010).The silicon fertilization significantly increased S uptake by grain due to increased availability of S in soil. These results are in agreement with the findings of Sumida (1992); Singh *et al.*, (2006); Osuna *et al.,* (1991) and Korndorfer *et al.,* (2001).Significant increase in S uptake within S levels could be due to increased availability of S in the soil from applied S with concomitant increase in grain yield. Vaiyapuri and Sriramachandrasekharan (2001) had reported increase in sulphur uptake by rice with increase in S levels earlier.

The maximum P uptake by rice grain (15.52, 15.92 and 15.72 kg ha^{-1}) was recorded due to application of 450 kg Si ha^{-1} during both the years as well as on pooled basis respectively. Addition of sulphur increased P uptake by grain and the maximum uptake was recorded at 40 kg S ha^{-1} during second year and pooled basis however, effect of sulphur was non-significant in first year. The maximum improvement was to the value of 13.94 per cent higher during pooled basis over control (Table 3). The maximum P uptake by rice straw (8.51, 9.45 and 8.94 kg ha^{-1}) was recorded due to application of 450 kg Si ha^{-1} during both the years as well as on pooled basis respectively. The P uptake in rice straw was higher with S_{40} compared to S_{20} and S_0 levels; however, it was at par with 20 kg S ha^{-1} during first year. The maximum improvement was to the value of 15.93 per cent higher during pooled basis over control (Table 4). Increasing silicon levels increased phosphorus content due to decreased retention capacity of soil and increased solubility of phosphorus leading to increased efficiency of phosphatic fertilizer (Subramanian and Gopalswamy, 1991). These results are in line with Chanchareonsook *et al.,* (2002) who reported that application NPK fertilizer in combination with Si significantly increased total N, P and K uptake of rice. The increased in P uptake by silicon application might be due to increase in soil available P as both of these nutrients are absorbed by plants. Phosphorus use efficiency is enhanced by silicon application and the beneficial effect of silicon is seen when available P is low it may due to partial substituting of silicon for P or an improvement of P availability in soil. On mineral soils with low soil pH, phosphorus present as complex with Al and Fe phosphate may become plant available with addition of silicon thereby increasing crop yield. Presence of silicon increased phosphorus concentration and P uptake due to enhanced phosphate absorption and it was attributed to the availability of silicate ions to displace the fixed phosphorus ions in the soil leading to increased phosphorus uptake. Depressing effect of silicate on P retention capacity of soil may be added reasons to increase the level of water soluble P in the soil. Hence, it can be inferred that the increase in the uptake of P with the application of silicon might be attributed to enhanced availability and uptake of nutrients from soil which is made possible by desorption of P (Subramaniyan and Gopalaswarmy, 1991). Higher P uptake in the presence of S could be due to the capacity of S in mobilizing soil P into available form. Muneshwar Singh *et al.,* (2001) reported that P and K uptake were stimulated in the presence of S.

In conclusion, application of silicon @450 kg ha^{-1} and sulphur @40 kg ha^{-1} recorded maximum Si, P and S content and uptake by rice in loamy sand soil under rice – wheat cropping sequence.

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